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Article

Local Knowledge of Pond Fish-Farming Ecosystem Services: Management Implications of Stakeholders' Perceptions in Three Different Contexts (Brazil, France and Indonesia)

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Abstract: This article addresses ecosystem service perceptions in the case of pond fish-farming systems in Brazil, France and Indonesia. The Millennium Ecosystem Assessment vision suggests a more integrated reflection on environmental policies with greater adaptability to local knowledge and the development of social learning processes, which tend to promote more sustainable changes in behavior and practice than do sanctions. This study considers a part of the identification of ecosystem services. It shows that perceptions differ with the context, and found few differences depending on the type of stakeholders (fish farmers and other stakeholders). From a methodological viewpoint, this paper opens up new prospects for valuing ecosystem services through a perception study.

Keywords: social perception; ecosystem services; valuation method; pond fish-farming systems

1. Introduction

The Millennium Ecosystem Assessment [1] proposes a structural change in the reference framework for environmental policies, stressing the importance of reconciling the natural environment

and human activities [1]. The ecosystem service approach includes several areas for research, such as identification, spatialization, monetarization, privatization and marketization of services [2,3]. Compared with the other areas, few studies specifically address the identification area. Yet it is generally accepted that the characterization of the services produced and used provides an operational framework for public policies [4].

In contrast, the monetary evaluation of services is very frequently undertaken, both to contribute to decision-making through cost-benefit studies or, more generally, to compare the weight and magnitude of such services. However, despite some improvement in the methods, this monetary approach continues to attract criticism. The main issues raised are not specific to ecosystem services and concern the assumptions about agents' preferences as well as measurement difficulties. For instance, Wegner and Pascual [5] emphasize the range of welfare economic dimensions that cannot be addressed though utilitarian and welfarist approaches. These authors note that "the results from environmental psychology confirm that ecosystems have relevance to human well-being far beyond the satisfaction of preferences including a strong bearing on psychological health, social integration and socio-cultural identity". Likewise, Hein *et al.* [6] highlight several constraints due to the range of viewpoints, depending on stakeholders and scales, together with double-counting risks [7]. They argue that it would be useful to categorize ecosystem services into intermediate services, final services and benefits in line with their economic definitions of services [8].

More generally, an analysis of the importance of these services and an assessment of their value has to build on prior knowledge. This is especially the case when, as stressed by TEEB [3], there is "no feeling of common heritage or legacy". Such knowledge varies with the actors and the areas. It can be addressed through the individuals' perceptions of these services [9]. These perceptions, which are central to risk analysis, enable the importance and the uses of these services to be identified and, through various methods, provide crucial input to public policies. They are particularly useful for understanding the acceptance of these policies [7,10] and, more importantly, for identifying potential voluntary agreements.

This vision suggests a more integrated reflection on environmental policies with greater adaptability to local knowledge and the development of social learning processes, which tend to promote more sustainable changes in behavior and practice than do sanctions [1]. These latter generate diversion strategies, whereas adaptability and social learning lead to appropriation. Such appropriation concerns two levels: (i) firstly, the appropriation of the ecosystem services by giving them value, not only use or exchange values, but also intrinsic value; and (ii) secondly, the appropriation of ecosystem management rules. Resource management is usually left to market forces, but ecosystem services lack the characteristics necessary for efficient market allocation, as they are non-excludable, non-rival, and damaged by negative externalities [11]. This change of reference framework increases the importance of more cognitive aspects to adapt public policies and promotes social learning.

We, therefore, studied these aspects through social perceptions. At the individual level, social perceptions determine the comprehension of behavioral development when facing regulatory measures to maintain ecosystems [10,11]. At the collective level, they determine the support for, and confidence in, the institutional mechanisms for the implementation of such measures. In addition, perceptions capture the degree of knowledge that the actors have of ecosystem services. Local ecological knowledge is an important element in the design and structure of natural management strategies [10,11].

This article addresses ecosystem service perceptions in the case of pond fish-farming systems in Brazil, France and Indonesia. The main goal of our research is the identification of the farmer and other stakeholder social perceptions in order to identify their knowledge of their working environment and the extent to which their perceptions correspond to the main measures of ecosystem management. This study considers part of the identification phase of ecosystem services. We worked in three countries with similar pond production systems but varying ecosystem and regulatory situations. In the first part, we outline the interest in studying perceptions and the methods used. The second part presents the cases studied. The third part presents the methodology we used to study social perceptions. The fourth part presents the results, which are then discussed in the fifth and final part.

2. Literature Review: The Interest in Studying Perceptions

2.1. Link between Perceptions and Environment

Social perceptions are organized and prioritized sets of judgments, attitudes and information of a given social group on a given topic [12]. Seca [13] argues that "*there are socio-cognitive and behavioural programmes affecting groups and their members*". The study of perceptions originated in sociology and psychology. Their application to environmental issues led to the development of environmental psychology [14] and its various currents depending on which factors are highlighted. They may be reduced to the so-called psychometric approaches [15], which focus on individual factors, and the culturalist approaches [16], which stress the role of social values and perceptions [17]. In practice, analyses usually include both types of factor. These aspects are at the heart of the economics of conventions. Understanding actor perceptions clarifies if collective conventions to which they refer and facilitates the development and implementation of coordination mechanisms exist. In particular, avoidance behavior with respect to norms and control measures can be reduced [18]. Livet and Thévenot [19] underline the role of collective conventions to make individual actions converged. Beuret [20] suggests that "*more flexible regulation on a case by case basis would be more effective than rigid poorly complied-with rules*". These conventions may be considered as "*collective cognitive arrangements*" [21] or as "*a set of collective behavioural rules*" [22]. This approach emphasizes institutional change processes [23], especially concerning meta-standard changes [24]. Such changes must be progressive and be accompanied by gradual implementation processes. This is the same principle of continuous improvement that is found at the core of the sustainable development framework and in the recommendations of the sociology of innovation concerning the adoption of new benchmarks [25].

2.2. Relevance of Perceptions in Environmental Policies

Although it has been little studied, the identification of the services provided is of strategic significance in the implementation of environmental public policies. Ultimately, the existence of an ecosystem service depends on the existence of a demand or a use (direct or indirect) or else on the recognition of a value (option or existence value). It is this demand or use that determines the contribution to social welfare. According to Bussard *et al.* (1998), cited by Schneiders *et al.* [26], *"Ecosystem management is managing areas at various scale in such a way that ecological services and biological resources are restored and conserved".* Balmford *et al.* [27] argue that the reasons and the values that underpin the interest of ecosystem preservation for human societies can be understood if

perceptions are taken into account. These reasons and values allow farmers to become "*both production and ecosystem managers*" (Tilman *et al.*, cited by Dale and Polasky [28]). The identification of perceptions contributes to an improvement in the adaptation of measures and incentives that are put into place and hence in their increased acceptance by the actors [29]. The identification of services thought to be important by actors is a step towards understanding actors' perceptions and therefore their values. This means, in particular, identifying (i) particular target groups requiring specific accompanying measures; and (ii) the level of knowledge of services in order to define awareness-raising actions. Such actions should not be restricted to information, as not only the practices but also the values underlying these practices must be changed. Appropriation of environmental values favoring the recognition and conservation of ecosystem services requires specific organizational and institutional learning, so-called double-loop learning [30].

Numerous studies in environmental psychology have attempted to define the factors leading to the pro-environmental attitudes of environment conservation and protection and for consumers [31]. Among the most commonly studied are individual characteristics such as age, gender and education. Controversies surround the influence of age and gender but it seems that education and information have a consistent positive impact. This includes not only formal education but also tacit knowledge acquired through familiarity and proximity with the environment depending on use [18]. Several authors [32–35] show that actors' motivations and perceptions towards environmental conservation involve values of surpassing oneself. Those who are most sensitive to environmental conservation are often defined as altruistic compared to others who are more preoccupied with their short-term well-being and are seen as selfish. Most studies use the Schwarz value survey. Other collective factors such as social networks, and the standards and nature of management arrangements are also involved. Giddens [36] notes the importance of governance arrangements and more broadly of the trust in public agencies as a central condition for public policies to be accepted, which explains the importance of governance research [33,37]. The diagram below (Figure 1) shows our analytical structure. It summarizes the main components of the interactions between ecosystem services and socio-economic systems, showing in particular that users' perceptions are determined by both individual (social) characteristics and collective (public policy) characteristics.

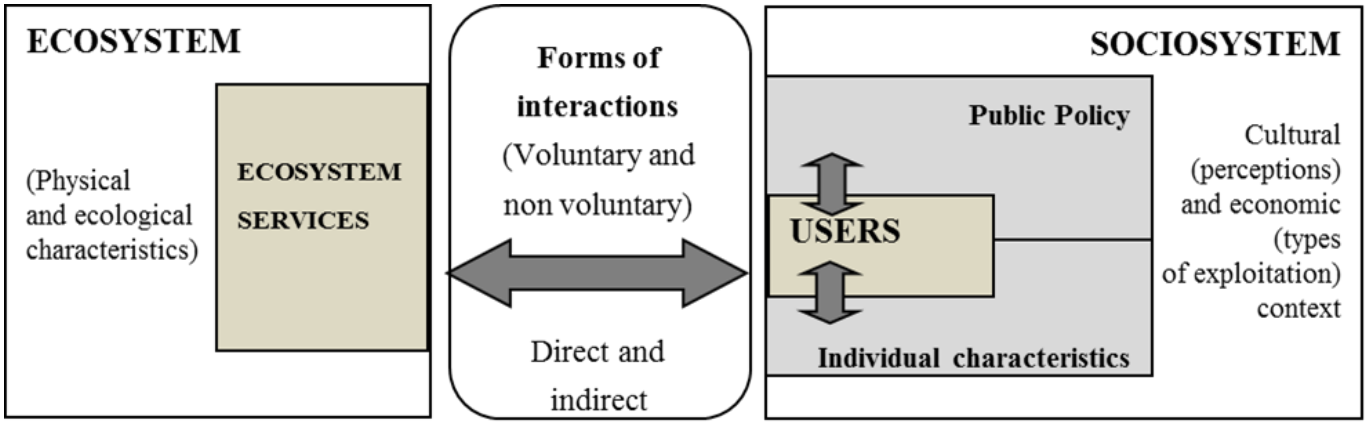

Figure 1. Analytical structure.

2.3. Need to Study Perception Diversity

Regardless of the determinants of behavior, analyses of perception tend to show that the range of uses and values depends on the context [38,39] implying that knowledge, social recognition and even social demand with respect to ecosystem services vary according to both the type of actor and the area concerned [40]. In order to be adapted, policies must therefore be defined and implemented according not only to the degree of anthropization (as noted by Schneiders *et al.* [26]) but also to the scales and contexts [6]. Prior to the monetary evaluation, some studies suggest qualitative or deliberative approaches (Sagoff, 2004 cited by Chan *et al.* [41]). These are particularly recommended when service uses are little developed and specific to a limited area [7] or when they depend on complex processes as with cultural services [41]. Chan *et al.* [41] decry the small number of alternative methods. They mention the multi-metric approach most often based on focus groups and collective evaluations. This approach uses "*subjective scaling when necessary*" [41] *or "ordinal ranking or numeric tag"*, or the creation of an index from 1 to 5 or 1 to 10. According to Chan *et al.* [41], "*many such constructed scales are in widespread use in society. Constructed indices can greatly facilitate a manager's decision by defining precisely the focus of attention and by permitting tradeoffs across different levels. Such a constructed index can focus a decision maker's attention on tradeoffs with other attributes and questions*". With that in mind, we designed a survey protocol to address perceptions of services and thus study their significance for actors and users without resorting to monetary evaluation. This type of approach converges partly on the issue of subjective indicators relating to people's satisfaction as a function of their perceptions about well-being. As Frey *et al.* [42] point out, these subjective approaches are less likely to lead to strategic responses. Nevertheless, this situated evaluation [43] depends on the context and means that all the levels at which ecosystems intervene and contribute to well-being must be taken into account.

3. Materials and Methods

3.1. Surveys in Highly-Contrasted Contexts

As part of a French research project (Piscenlit) funded by the National Research Agency, we identified ecosystem services provided by fish-farming ponds. The project seeks to identify ways to achieve ecological intensification [44] in fish-farming ponds to produce ecosystem services as both a pillar to sustain production and a means to diversify production. We studied three sites in Brazil, France and Indonesia (Figure 2):

- Recent multi-trophic systems based on recycling of effluents and utilization of byproducts with low nutritional value in Brazil (Santa Catarina State). Businesses are family-run and use earth ponds. The activity is associated with recycling farming effluents and the utilization of low-food-value inputs. Survey sites were selected in two areas of particular interest: the High Valley of Itajai in the East where the activity is highly structured, and that of Chapeco in the West where the organization is weaker, as it is in the rest of the region. These activities are situated in areas with large topographical variations. New laws have been implemented in order to professionalize the sector and reduce environmental impacts. They establish permanent preservation zones, "APP" (*Area de Preservacion Permanente*), and require installations to be at least 30 m from rivers. These measures seek to preserve the vegetation, the biodiversity and the functions of riverbanks. Training was provided for fish farmers in the Itajai area through an organization (Mavipi), within which all

producers adhere to the same environmentally-friendly production method. The output goes either to the Sao Paulo market or for processing.

- Ancestral systems of extensive polyculture in France (Lorraine and Brenne) associated with recreational activities (angling, walking and nature observation). Brenne and Lorraine are key regions in pond aquaculture, representing 10% and 7%, respectively, of national production [45]. The production is mainly intended for enhancement (70% in Brenne and 90% in Lorraine). Many enterprises welcome visitors (fishing runs, fish sales on site, open days, and nature observation). These are situated in specific wetland areas subject to conservation measures (Natura 2000 or Ramsar sites). The activities in these areas are heavily regulated by environmental standards, especially the European Water Framework Directive. In Lorraine, agro-environmental measures have been implemented to strengthen the contribution of fishponds to environmental conservation. In Brenne, the ponds are part of a Regional Natural Park. Hence, in both regions, fishponds are key contributors to the nature of the landscape and the maintenance of biodiversity. Brenne, for example, is called the 1000-pond region. This feature contributes to its tourist attractiveness, particularly for nature tourism.
- Recent systems of semi-extensive monoculture in Indonesia (Tangkit and Kumpeh villages, Jambi Province). These activities are situated in areas focusing on pineapple crops. It is therefore a recent sector born of the conversion of agricultural holdings that have adopted traditional Javanese fish farming practices. These holdings are small and family-run (less than 1 ha in 98.5% of cases). Fish farming is carried out mainly in ponds dug for this purpose. Growth has recently slowed as a result of crises related to price instability and increasing feed cost due to pathologies, which are related to monoculture. In response to this crisis, which has led to a drop in the number of holdings, there has been a diversification of species and a growing awareness of environmental issues. These activities are heavily guided by the Minapolitan regulation, which aims to increase production by 353% by 2015. The objective of this program, managed by the Ministry of Marine Affairs and Fisheries (KKP), is to raise Indonesia, currently ranked fourth in global fish production, to first place.

Table 1 summarizes the characteristics of the pond fish-farming systems studied.

Table 1. Main characteristics pond fish-farming systems in the study area.

	Brazil	**France**	**Indonesia**
Surface Area (ha)	349 (Chapeco) 157 (Alto Vale do Itaja i)	7000 (Loraine) 8800 (Brenne)	292,000
Number of farms	932	242	576
Annual production (mt)	2373	2054	6935
Reared species	Tilapia, Common carp and Chinese carp	Common carp, roach, common rudd, tanch, pike, perch, pike perch	Catfish
Marketing	Local market and Sao Paulo market	Local restocking or fishing activities	National market
Specificities	Combined pig and pond system	Extensive polyculture; Many enterprises welcome visitors	Semi-extensive system with feed distribution
Productivity (mt/ha/year)	9.5–12	0.1–0. 4	89.9

Source: Brazil: Pro-mover and ADEMAVIPI [46], EPAGRI/CEDAP [47], France: FLAC [45], Indonesia: [48].

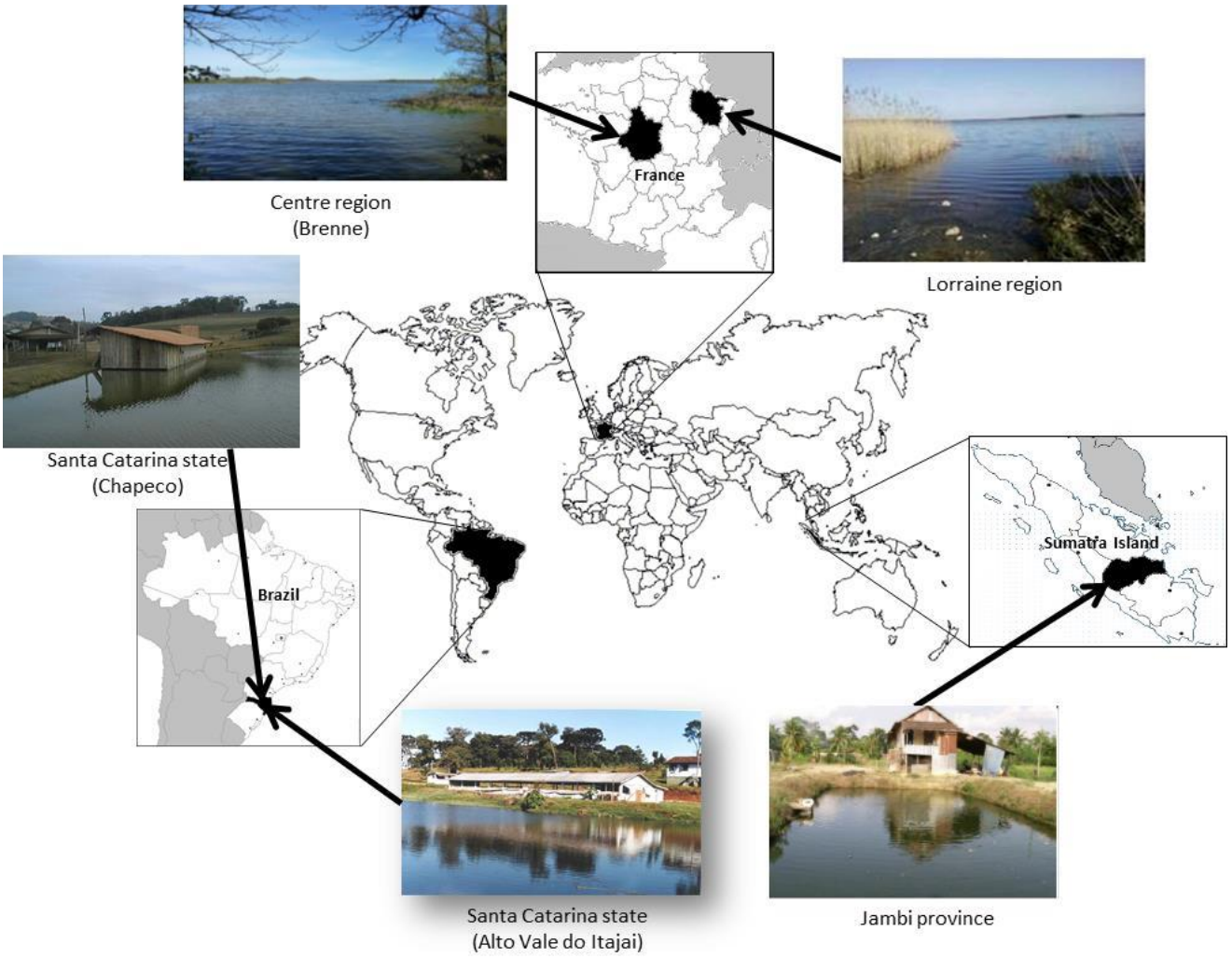

Figure 2. Map of the three study sites.

3.2. Methods

Few publications concern ecosystem services relating to pond farming. As no generic list specific to fish farming was available, we adapted the MEA list [49] to the case of pond farming in order to provide a reference list for the surveys. This adaptation was undertaken by the multidisciplinary group of researchers who are partners in the PISCEnLIT project using the literature and their knowledge [50]. The list was operationalized according to the specific context of each site. This operationalization was facilitated by many years' research experience at the study sites and by partnerships, in accordance with the recommendations and findings in the literature. This list contains 28 ecosystem services.

To assess local knowledge and ecosystem service perceptions, we interviewed farmers and stakeholders (Table 2) using semi-structured questionnaires that were developed on a multidisciplinary basis. Face-to-face surveys varied according to the context and lasted a couple of hours on average. In order to take diversity into account, the fish farmer sample was drawn from a stratified sampling frame.

Learning about perceptions requires adapted survey protocols [51–55], which purposely combine closed questions in order to establish typologies and open questions in order to analyze the spontaneous perceptions of interviewees. The questionnaire design took into account this recommendation. It

combined open (spontaneous perceptions) and closed questions (ranking according to a pre-determined scale [56]). Following Kaplowitz and Hoehn [52], the open questions, placed at the beginning of the questionnaire, enabled perceptions to be identified without mentioning the notion of ecosystem services. The interviewees were then asked to rank the 10 services they valued most from a reference list. Given the large number of services and to avoid memorization issues, ranking was noted directly by the interviewee in the summary table. Unlike open questions, this list suggested services that may not spontaneously spring to mind. As well as the perception of services, the multiple structural and functional features of enterprises were also to be studied. In this paper, we analyze the responses to closed questions. A comparison between responses to open and closed questions is proposed in another paper.

Table 2. Structure of surveyed samples.

	Brazil		**France**		**Indonesia**	**Total**
	Chapeco	**Itajai**	**Lorraine**	**Brenne**		
Number of enterprises	690	242	42	200	576	1750
Diversity in enterprise type	Two types	One type only	Very high	One type only	Two types	-
Surveyed sample	50	25	25	33	34	167
Sampling ratio	7%	10%	59%	17%	6%	10%
Number of other stakeholders surveyed Of which:	34		59		9 *	102
State and administrative authorities	14		31		2	47
Associations and professional organisations	5		15		1	21
Downstream and upstream value chain	15		13		6	34

* 29 stakeholders interviewed but only 9 ranked the services.

Two indicators were calculated from the prioritized services:

- citation frequency, which represents the number of times each service was selected and therefore considered important; and
- an average score, which is the sum of scores obtained during the prioritization of those services that were considered to be the most important.

In order to identify the nature of the services most frequently mentioned, we used the citation frequencies, which turned out to be the most reliable data, regardless of country. In Brazil, as fish farmers found it difficult to rank the services, there was insufficient data in terms of score by service to be usable. Hence, in order to compare the three countries, we calculated for each service the percentage of producers and of other stakeholders who mentioned this service compared to the total number of producers and other stakeholders interviewed in each country.

Given the great diversity of services, we decided to analyze the results by classifying services using several macro-categories. Rather than use again the widely-used categories of direct and indirect services [7], we opted to use categories based on the value of the natural capital proposed by Petrosillo *et al.* [57]. Petrosillo *et al.* [57] distinguish nine categories, which we have grouped into three: (1) the economic value related to the economic opportunities generated by the ponds; (2) the biological value related to the supporting and regulating services; and (3) the cultural value ,which refers to heritage and recreational services.

Thus, in this paper, we allocated the listed ecosystem services to three value categories (economic (8 services), biological (8 services) and heritage (12 services)) and, using a comparison method, we analyzed the service selection percentage (citation frequencies related to number of producers or other stakeholders) mentioned for producers and other stakeholders. Summary tables showing all the results obtained by decreasing order of frequency are presented in the supplementary material section (Tables A1 and A2; the ten top selected services are highlighted in grey in the table).

4. Results

Given the significant number of services and our objective of comparing perceptions in three different countries, we decided to present the results in two ways, by service types and, generally (perceptions were compared between countries and between fish farmers and other stakeholders), according to the nature of their economic, biological and heritage value.

4.1. Results Per Nature of the Value of the Services

4.1.1. Comparing Perceptions within Services of Economic Value

Eight services (Figure 3) were found to present economic opportunities for producers. We found that Indonesian actors have the widest vision of this type of service. In Brazil and in France, the services selected by fish farmers and other stakeholders were fish production and the freshwater reservoir (the latter only for Brazil).

Fish production with its long history remains strongly present in perceptions despite the fact that it has become rather marginal. In France, and in particular in Lorraine, ponds were created by monasteries during the Middle Ages with the aim of developing fish consumption in non-coastal zones. This objective had much to do with the religious custom of eating fish on Good Friday. Until the French revolution, ponds were the domain of the wealthy classes and some 90% of them were the property of the nobility and the clergy [58]. This food supply function has greatly diminished and a large number of French pond farms are now producing fingerlings, either for restocking or for fishing activities with conservation or recreation in mind. Nowadays, pond conventions reward efforts made by fish farmers to maintain the environmental quality of their ponds. However, in anticipation of a fall in restocking demand due to the eventual banning of this practice in rivers, the industry is attempting to re-start consumption, in particular locally, drawing on the heritage character of this activity and on traditional recipes. In the case of France, despite the ancient origin of the activity, there are no services with a frequency over 50%, which explains the relatively weaker position than in other countries. However, it is in France that the diversity of heritage services mentioned above is the most important.

In Brazil and in Indonesia, the economic provisioning functions, mainly fish and freshwater but also fertilizer and plants in Indonesia, are the ponds' primary functions. These are developing countries where nutritional objectives are determinant, in particular in rural areas where poverty reduction policies emphasize the issue of food supply to local populations. Apart from this nutritional aspect, the differences between the countries may also be explained by the history of pond fish farming development and the nature of their integration in the areas.

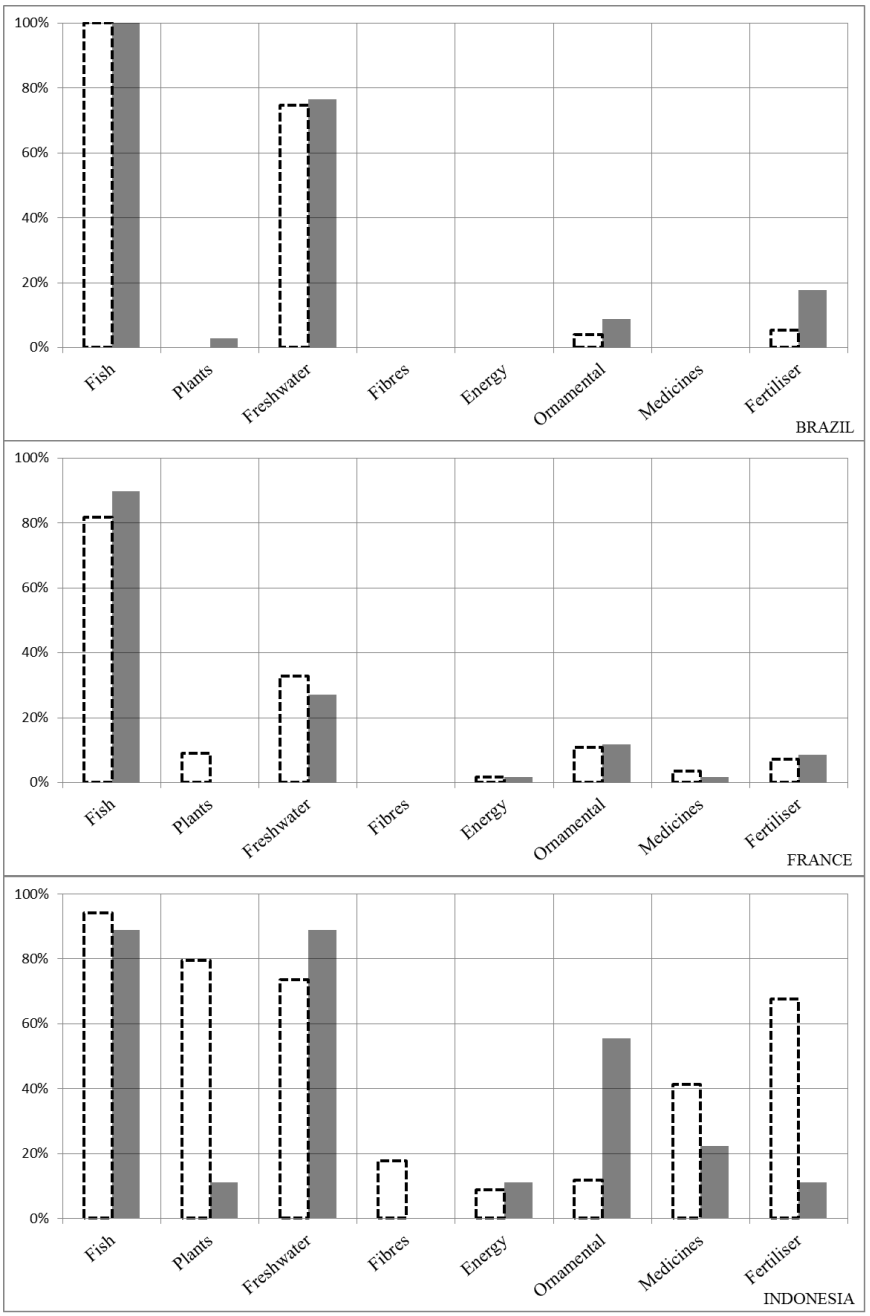

Figure 3. Fish farmers' and other stakeholders' selection percentage of services with economic value.

In Indonesia, it is services with economic value that were selected. Great importance is given to production. Since 2010, the Minapolitan law, which aims to increase production by 353% and raise productivity, has had a large impact on perceptions, as the Tangkit area is a pilot zone. As well as improved product quality, this law calls for "community" empowerment, which gives an important place to know-how. As in Brazil, the ponds are gradually generating leisure activities. These water bodies are tending to become walking areas for the local population and fishing activities are also developing.

Besides fish production, which is common to all countries, the diversity of supply services is greatest in Brazil and Indonesia, with freshwater reservoir and fertilizer supply, or plant production functions in Indonesia.

4.1.2. Comparing Perceptions within Services of Biological Value

Figure 4 shows that there was greater interest for services with biological value in Brazil and France. In Indonesia, only the other stakeholders select significantly a diversity of such services. Information relating to these services is much more widely disseminated in Brazil and in France, in particular through incentives that reward environmental services but also through restrictive measures arising from the legislation (e.g., FPA in Brazil or Water Framework Directive in France). In Indonesia, this type of information is somewhat less disseminated as incentives are more focused on increasing production, even if they include an environmental component.

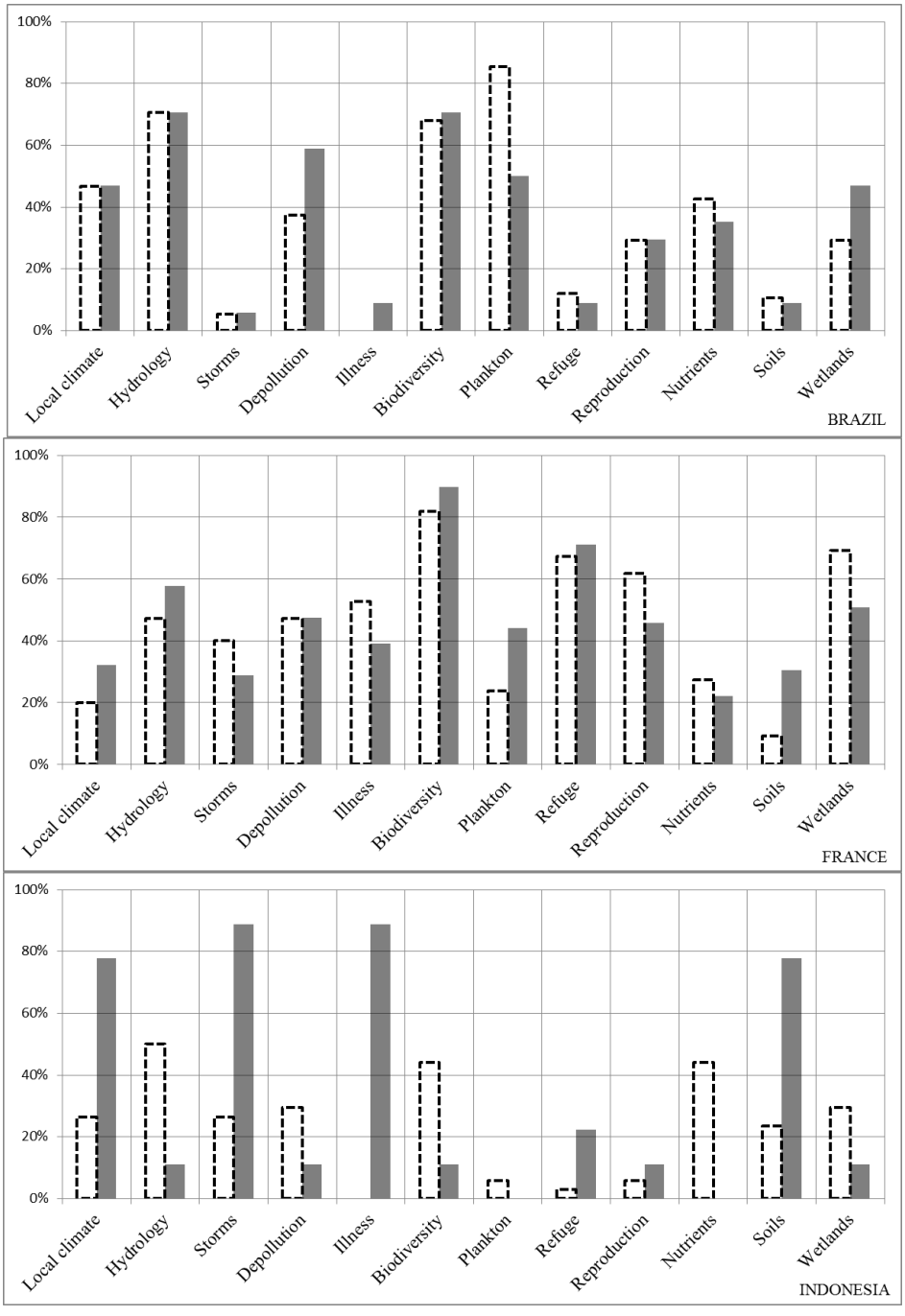

Figure 4. Fish farmers' and other stakeholders' selection percentage of services with biological value.

In the south of Brazil, production is not the primary activity because it is associated with the recycling of effluent from pig farming. Ponds were built at the instigation of the Federal State in the 1980s following a severe drought with the principal aim of creating freshwater reservoirs. Both Brazilian fish farmers and other stakeholders stress the role played by ponds during drought. Producers also insist on phytoplankton production related to the recycling function. However, both producers and other stakeholders highlight biodiversity protection. The actors are aware that the practice of recycling farming effluent puts heavy pressure on the environment, which they seek to reduce. The State has enacted a law creating permanent preservation areas and requiring installations to be at least 30 m from the rivers. Professional associations, in particular in Mavipi, advocate production methods that respect environmental constraints using agro-ecology principles [59].

In Indonesia, the importance of water regulation and storm protection can be explained by the buffer role of ponds in these areas, which are prone to flooding.

It is in the case of services of biological value that frequencies are the lowest. This may be because ponds are often built independently from watercourses and people's awareness of environmental consequences and of the advantages generated by these practices is of recent origin. Lastly, the profiles of the support and regulating services differ greatly depending on the importance and orientation of public environmental policies (existence of agro-environmental measures in France), type of farm (integrated pig-fish farms in Brazil that focus on phytoplankton production), and contexts (buffer role played by ponds during floods in flood-prone zones in Indonesia).

4.1.3. Comparing Perceptions within Services of Heritage Value

In Brazil and in France, the other stakeholders generally have a broader vision than fish farmers on services with a heritage value (Figure 5). In Indonesia, we again found a difference in viewpoint between fish farmers and other stakeholders for this category of service.

Likewise, the importance of landscape and recreation aspects, as well as leisure-fishing activities and hunting is explained both by lifestyle and the heritage character of ponds built in the Middle Ages. In Brazil, leisure and awareness-raising services are highlighted, due to their introduction as the principal activity of some enterprises along with a gastronomic element. In Indonesia, recreational aspects are recent and limited to fishing competitions. Also, the importance of know-how is explained by learning issues, which are related to the short history of the type of fish production studied.

4.2. Comparing Perceptions between Countries and between Fish Farmers and Other Stakeholders

4.2.1. Comparing Perceptions per Country

We observed large differences in perception linked to (i) the type of physical context, which influences the role of the pond (e.g., position in the watershed, size, number of ponds); (ii) the history and age of the fish-production activity; and (iii) the diversity of practices, uses, and public policies related to ponds. The table below (Table 3) summarizes the results according to the number and the importance of services mentioned in each country (number and percentage of services with a relative frequency over 50%). It shows a tension between the biological, and to a lesser extent the heritage, value

and the economic value. The respective importance of these values can be related to the history and age of fish farming activity in each country.

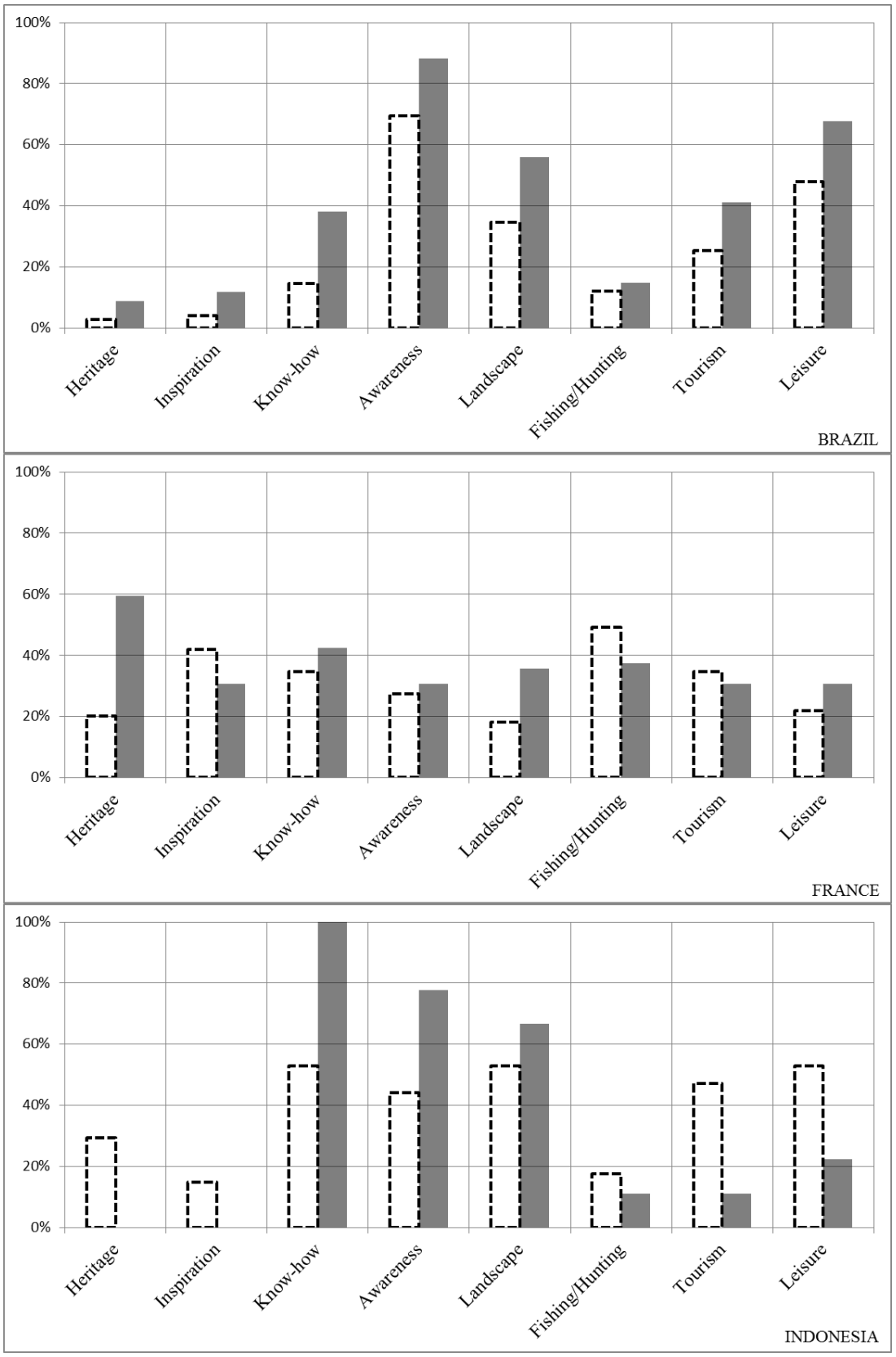

Figure 5. Fish farmers' and other stakeholders' selection percentage for services of heritage value.

Table 3. Summary of the relative importance of values as a function of the diversity and the citation frequency of ecosystem services (number and percentage of services with a relative frequency over 50%).

	Economic Value	Biological Value	Heritage Value
France	1 (13%)	5 (42%)	0 (0%)
Brazil	1 (13%)	3 (25%)	2 (25%)
Indonesia	4 (50%)	0 (0%)	3 (38%)

These differences may be explained first by the geographical characteristics of the areas and the forms of fish farming undertaken and second by the diversity of uses of, and public policies towards, the ponds. For example, pond areas in highly urbanized contexts such as France constitute "natural" and landscape areas, which are very attractive to both the local population and tourists, mainly ecotourism due to the presence of birds and nesting grounds in lagoons and wetlands. It should be noted that the hunting/fishing service (a heritage function in these areas) is only cited in France.

As shown by Hein *et al.* [6], in the case of the Dutch wetlands, the primary function is no longer the presence of anglers (fish farmers in our case) but the generation of significant cultural and heritage value. These values, related to environmental conservation, are strengthened by pro-conservationist public policies (Ramsar, Natura 2000, Nature Park). It should be noted that the service of biodiversity preservation has begun, in some regions, to be rewarded under agro-environmental measures. Fish farming has an important role to play here because in the absence of this activity there is a tendency to close lagoons to promote hunting, which is detrimental to biodiversity.

4.2.1. Comparing Perceptions per Country

Between types of actors (fish farmers and other stakeholders), differences in perception can be explained by differences in the scale of approach, levels and forms of knowledge (family-based or academic), as well as the degree to which the family is involved in fishponds. There are strong similarities in their viewpoints in France and Brazil, where information about ecosystem services is the subject of awareness programs or incentive measures. There are, however, a few differences: for example, the other stakeholders in France and Brazil have a wider vision than fish farmers about the heritage value of ponds. Likewise, in Brazil, the other stakeholders are more conscious of the importance of know-how and the part played by the landscape. In contrast, perceptions differ more in Indonesia, where fish farmers and the other stakeholders do not rank services in the same order. The degree of these differences is due to a certain institutional and cognitive "isolation" of fish farmers who are recently-converted farmers and thus have highly variable educational levels. The table below (Table 4) summarizes the differences observed as a function of the number of services where the frequency variation between fish farmers and other stakeholders is at least 15%. It shows very contrasting situations between France and Brazil on the one hand, and Indonesia on the other.

These differences in perceptions show the need to explore a wide diversity of viewpoints. Consideration of this multiplicity can help in understanding the diversity of position, which may restrict the acceptance of certain management measures.

Table 4. Summary of perception differences between fish farmers and other stakeholders (number and percentage of services where the frequency variation is higher than or equal to 15%).

	Economic Value	Biological Value	Heritage Value	Total
France	0 (0%)	2 (17%)	2 (25%)	4 (15%)
Brazil	0 (0%)	3 (25%)	3 (38%)	6 (23%)
Indonesia	4 (50%)	7 (58%)	4 (50%)	15 (58%)

Despite the differences observed between the countries, the comparison of perceptions between fish farmers and other stakeholders shows, in contrast with the literature, a large number of similarities for Brazil and France. These similarities may, perhaps, be explained by the indicators that we were forced to use, as citation frequency is a less subtle measurement of perceptions than service ranking scores. The scores tend to emphasize the differences [55,60].

5. Discussion

5.1. Comparing Perceptions

In line with the literature [6,7], our observations show that service perceptions differ with the context. Generally, such differences between fish farmers and other stakeholders can be explained by differences in scales or knowledge. As noted by Hein *et al.* [6] and Fisher *et al.* [7] "*Stakeholders at different spatial scales have different interests in ecosystem services"* [7]. Alongi (2002) also shows that local residents prefer provisioning services whilst wishing to maintain regulating services and that national and international actors are essentially preoccupied by the loss of mangroves and biodiversity. In our case, similarities are mainly due to very specific governance systems of the value chain in Brazil and in France. In the case of France and in particular in Lorraine, there are few fish farmers and they tend to be as highly educated as other stakeholders. But the most important factor is that there are close ties between industry and research organizations leading to the dissemination and appropriation of the standards underpinning public policies. In one Brazilian site, fish farmers have a similar close relationship, not with research but with a well-structured and very active association: ADEMAPIVI, which acts as an interface between research and government. This association is developing a specific MAPIVI operating model which integrates strong awareness of the environment and agro-ecological principles [59]. Precise practice guidelines and training for the industry are defined on this basis. By contrast, in Indonesia, the level of education is generally low in the industry, which tends to be somewhat isolated institutionally and cognitively. It should be noted that most producers are farmers who have only recently turned to fish farming. Indonesian fish farmers appear to have a broader vision of the economic opportunities provided by pond aquaculture. This is due to their risk management strategy, which is based on diversifying their activities. The production of ornamental fish was identified by the other stakeholders, but it requires a degree of technical expertise, concerning the selection of ornamental fishes for example, that goes beyond existing local knowledge.

5.2. Contribution to Decision-Making and Evaluation

Several authors stress the value of a holistic and integrated approach in improving interactions between human activities and environment. The ecosystem service approach provides a potential mode of action which can be guided by the market, the State (respectively "invisible" and "visible" hands) or by human values [61]. The latter approach, called "the third hand" by Wang *et al.* [62], may be complementary in the management of ecosystem services insofar as values affect preferences and have an impact on decision-making and individual and collective behavior. The same logic underpins the economics of convention which is why "*cultural values and social norms exert strong influences on and can dominate socio-economic policies*" [62]. Taking values into account through the analysis of perceptions thus represents a new approach in economics which leads to a questioning of the nature of the evaluation [63] to support the public decision-making process. Evaluation is indeed essential to assist decision-making in service management. Such evaluations can be monetary or non-monetary and both are important for decision-makers [64]. According to Daily *et al.* [64], there is a genuine need for non-monetary methods in service evaluations. The measurement of the value of services is multidimensional and varies by type of actor. Using non-monetary methods takes into account the diversity in viewpoints, the order of preferences [65], and the incommensurability of nature [66], and is in line with the adaptive and participatory governance of natural resources suggested by Ostrom [67]. This type of adaptive approach allows for the integration of changes in preferences that occur over time [68,69].

6. Conclusions

The aim of our analysis was to demonstrate the interest in studying perceptions in support of public policies. We hypothesize that an understanding of the services provides a positive signal towards the acceptance of policies for their conservation. One important element in the ecosystem approach is local knowledge supported by knowledge transferred by stakeholders, awareness-raising initiatives and the knowledge internalized by the actors [30]. Local knowledge is very important because it facilitates the understanding of complex context-specific ecosystem processes. The integration of this type of knowledge can help to develop production practices, for example towards agro-ecological benchmarks [59]. Commercial aquaculture has tended to lead to the loss of tacit know-how that may be the cornerstone in the implementation of ecosystem service management [70]. However, a certain degree of inertia must be taken into account, related, for instance, to the career paths of fish farmers, which emphasize the importance of knowledge transfer and of capacities for new learning [70].

We should highlight the fact that ecosystem management measures may be improved if they integrate locally-based information provided by farmers using social perceptions with global and empirical perspectives provided by scientific data. Local knowledge often provides guidelines and new information for ecosystem management and reciprocally strong regulatory measures influence perceptions. In fact, Silvano *et al.* [11] argue that "*a landowner with incomplete knowledge of the ecosystem services provided may therefore give them less weight than direct market benefits*". This observation argues for the involvement of farmers in the development of ecosystem management schemes. This involvement has to extend to the more general unit of stakeholders [65].

Our surveys, undertaken in three very different contexts (Brazil, France and Indonesia), have shown, in line with previous research, that perceptions differ with the context, and in particular in our case, with the history and age of the fish farm in the relevant territories. On the other hand, with the exception of Indonesia and apart from a few differences depending on the type of actor, perceptions were found to be fairly similar between fish farmers and other stakeholders. Compared to previous research, these similarities are novel and may be explained by the governance systems in place within the value chains.

This study of the perception of services was undertaken, service by service, in given sites. New and more global issues must also be addressed. Barbier [71] recommends a spatial approach to the distribution of these services. This type of approach provides an opportunity to reflect on the interactions between services and threshold effects in the conservation of a service. For example, the evaluation carried out by Barbier [71] of services relating to nursery grounds and the protection of mangroves and wetlands against storms showed that a minimum size was necessary if these two services were to be sustainable. These threshold effects require the recognition of ecological solidarity between territories [72]. They also require a change of scale in the implementation of conservation policies towards ecological corridors [49] that link protected areas. Furthermore, ethical issues must also be considered as they can play a role in the equitable distribution of these services as ecological amenities. This leads to the heavily-studied issue of ecological inequalities. Such spatialized approaches require the services of geographers and the integration of multilevel governance processes.

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Author Contributions

Syndhia Mathé and Hélène Rey-Valette were involved in the conception and design of the questionnaires. Syndhia Mathé analyzed the data. Both authors wrote the paper. Syndhia Mathé contributed to research materials and analysis tools. Hélène Rey-Valette contributed to the literature review and theoretical foundations. All authors gave thought to the discussions and conclusions parts. All authors read and approved the submitted manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

Appendix

Table A1. Presentation of the services selected by fish farmers in each country (% of fish farmers having selected this particular service).

Brazil		France		Indonesia	
Fish/crustacean production	100%	Fish/crustacean production	82%	Fish/crustacean production	94%
Plankton production	85%	Maintenance of biodiversity	82%	Food plant production	79%
Freshwater reservoir	75%	Refuge and nesting	67%	Freshwater reservoir	74%
Water regulation	71%	Spawning and reproduction areas	62%	Supply of fertilizer for agriculture	68%
Raising environmental awareness	69%	Participation in natural nutrient cycles	62%	Learning of "know-how"	53%
Maintenance of biodiversity	68%	Hunting and fishing	49%	Landscape and attractiveness	53%
Leisure	48%	Pollution storage, depollution	47%	Leisure	53%
Local climate regulation	47%	Water regulation	47%	Water regulation	50%
Participation in natural nutrient cycles	43%	Source of inspiration	47%	Tourism/ecotourism	47%
Pollution storage, depollution	37%	Protection against storms and floods	40%	Maintenance of biodiversity; raising environmental awareness	44%
Pollution storage, depollution	37%	Protection against storms and floods	40%	Participation in natural nutrient cycles	44%
Landscape	35%	Learning of "know-how", tourism	35%	Medical resources	41%
Spawning and reproduction areas; Protection of wetlands	29%	Freshwater reservoir	33%	Protection of wetlands	29%
Spawning and reproduction areas; Protection of wetlands	29%	Freshwater reservoir	33%	Pollution storage, depollution	29%
Tourism	25%	Raising environmental awareness	27%	Heritage resources	26%
				Protection against storms and floods	
Tourism	25%	Participation in natural nutrient cycles	27%	Local climate regulation	26%
Learning of "know-how"	15%	Leisure	22%	Soil maintenance	24%
Hunting/Fishing; Refuge and nesting	12%	Local climate regulation	20%	Fibre production	18%
Hunting/Fishing; Refuge and nesting	12%	Heritage resources	20%	Hunting and fishing	18%
Soil maintenance	11%	Landscape	18%	Inspiration	15%
Protection against storms and floods; Fertilizer for agriculture	5%	Ornamental resources	11%	Ornamental resources	12%
Inspiration; Ornamental resources	4%	Plant production	9%	Energy production	9%
Inspiration; Ornamental resources	4%	Soil maintenance	9%	Energy production	9%
Heritage resources	3%	Supply of fertilizer for agriculture	7%	Plankton production. Spawning and reproduction areas	6%
Heritage resources	3%	Medical resources	4%	Refuge and nesting	3%
		Energy production	2%	Refuge and nesting	3%

Source: 2011 surveys Piscenlit project.

Table A2. Presentation of the services selected by other stakeholders in each country (% of other stakeholders having selected this service).

Brazil		France		Indonesia	
Fish/crustacean production	100%	Fish/crustacean production	90%	Learning of "know-how"	100%
Raising environmental awareness	88%	Maintenance of biodiversity	90%	Fish/crustacean production	89%
Freshwater reservoir	76%	Refuge and nesting	71%	Freshwater reservoir	89%
Water regulation	71%	Heritage resources	59%	Protection against storms and floods	89%
Maintenance of biodiversity	71%	Water regulation	58%	Disease regulation (human and fish)	89%
Leisure	68%	Protection of wetlands	51%	Raising environmental awareness	78%
Pollution storage, depollution	59%	Pollution storage, depollution	47%	Local climate regulation	78%
Landscape and attractiveness	56%	Spawning and reproduction areas	46%	Soil maintenance	78%
Plankton production	50%	Plankton production	44%	Landscape and attractiveness	67%
Local climate regulation; protection of wetlands	47%	Learning of "know-how"	42%	Ornamental resources	56%%
Tourism	41%	Disease regulation	39%	Medical resources; Leisure; Refuge and nesting	22%
Learning of "know-how"	38%	Hunting and fishing	37%	Energy production; plant production; fertilizer for agriculture; hunting and fishing; tourism; water regulation; maintenance of biodiversity; protection of wetlands; spawning and reproduction areas	11%
Participation in the natural nutrient cycles	35%	Landscape	36%		
Spawning and reproduction areas	29%	Local climate regulation	32%		
Supply of fertilizer for agriculture	18%	Tourism; leisure; soil maintenance; raising environmental awareness	31%		
Hunting and fishing	15%				
Inspiration	12%	Protection against storms and floods	29%		
Refuge and nesting; ornamental resources; heritage resources; soil maintenance; medical resources	9%	Freshwater reservoir	27%		
		Participation in the natural nutrient cycles	22%		
		Ornamental resources	12%		
		Supply of fertilizer for agriculture	8%		
Protection against storms and floods	6%	Energy production; medical resources	2%		

Source: 2011 surveys Piscenlit project.

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